

Measuring and modeling soil intra-day variability of the 13CO2 & 12CO2 production in a scots pine forest

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INRA SCIENCE & IMPACT

UNIVERSITÉ DE LORRAINE

MEASURING AND MODELING SOIL INTRA-DAY VARIABILITY OF THE 13CO2 & 12CO2 PRODUCTION IN A SCOTS PINE FOREST

Longdoz Bernard, Goffin S., Parent F., Plain C., Epron D., Wylock C., Haut B., Maier M., Schack-Kirchner H., Aubinet M.,

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ULB UNIVERSITÉ LIBRE DE BRUXELLES

Background

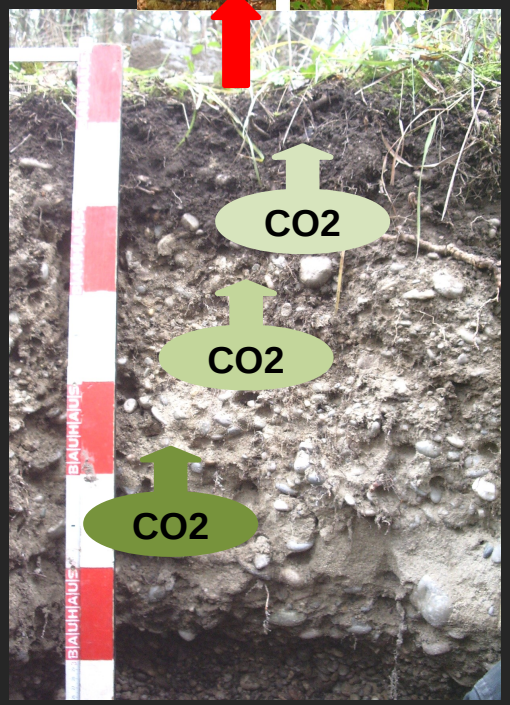
Past — today — Future

Soil CO2 efflux (***Fs***)

Empirical description → **Mechanistic understanding**

Climate Change Impact & Positive feedback ?





Fs

Transport

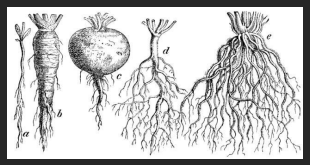
Diffusion

Advection + Dispersion

Liquid phase

Production

Autotrophic



Heterotrophic

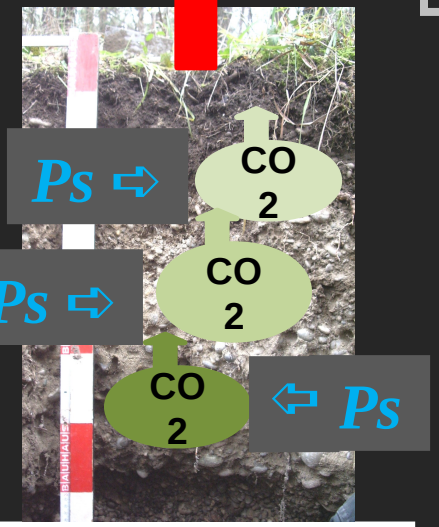


Abiotic

Fs

Transport

ƒ(porosity, humidity…)

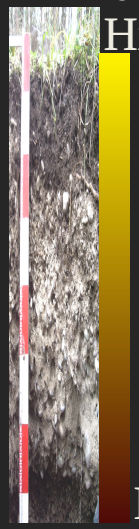


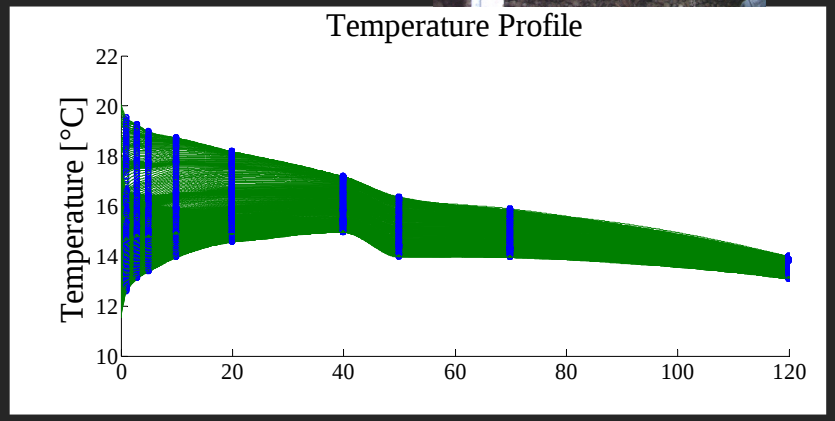
Production *Ps*

Heterotrophic **Autotrophic**

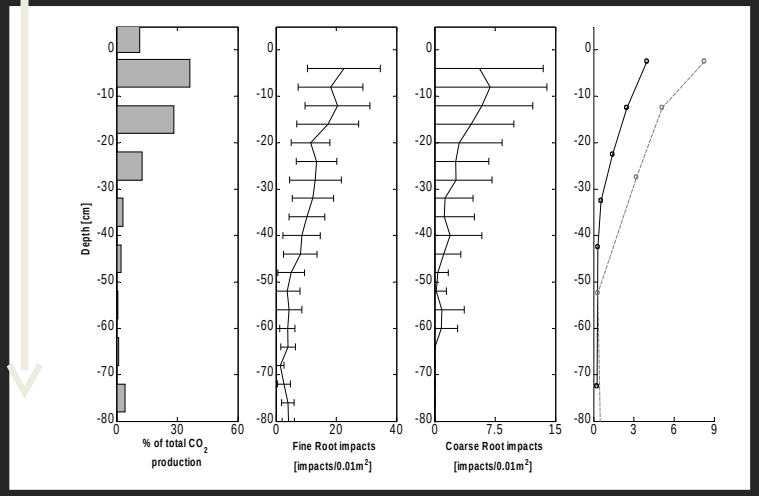
ƒ(Temperature, humidity, substrate, pH,…)

Porosity





Fine and Coarse Roots Corg



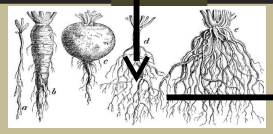
⇒ Multilayer Approach needed

□13CO2 atm ≃ -8‰

□13Cleaf = □13CO2 atm + Δphoto(climate) ≃ -27‰

□13Cphloem

□13*Fs*



□13*P*aut o

□13 *Ps*



□13*P*heter o

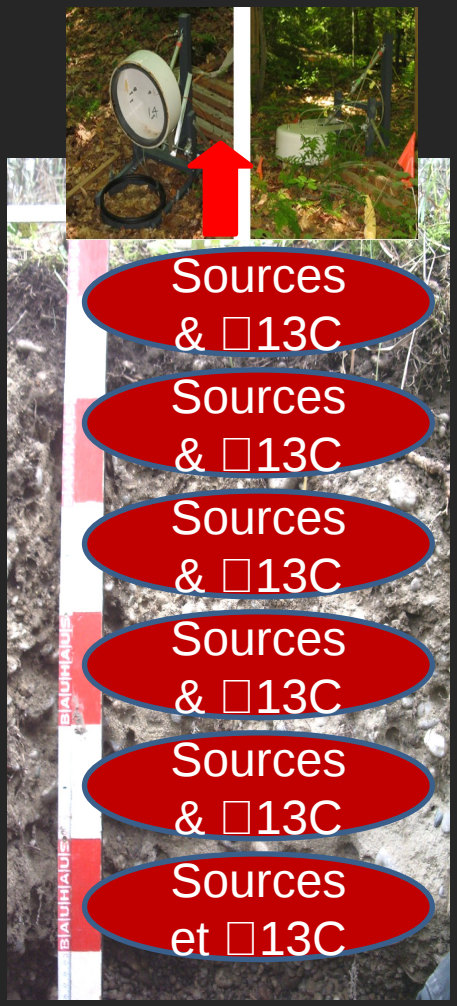
Temporal variation of 13Ps give information about transfer time and pathway of photoassimilates in the

13Ps fluctuations help for source partitioning kinetic

⇒ Quantify the δ13Ps temporal fluctuations

Objectives

Improving mechanistic understanding of ***Fs*** and ***Ps***

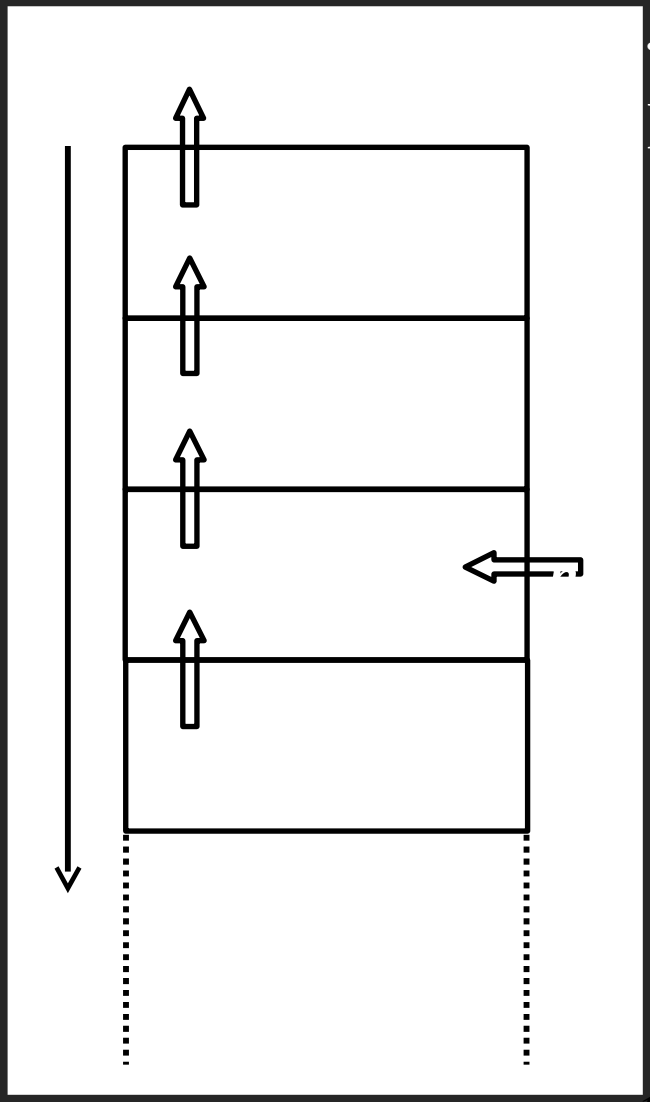


Multilayer Approach

Isotopic Signal Analysis

1) Determine ***Ps*** and ***13Ps*** for the different soil horizons.
2) Find factors affecting ***Ps*** & ***13Ps*** intra & inter day fluctuations
3) Evaluate by modeling what is the part of ***Ps*** in the ***Fs*** temporal variability

1. Determine *Ps* and δ13*Ps* for ≠ layers



· 12CO2 & 13CO2 mass balance for the nth layer:

$$\frac{\Delta\left(\varepsilon_n * C_n^{12-13}\right)}{\Delta t} = \frac{F_{n+1}^{12-13} - F_{n-1}^{12-13}}{thick_n} + Ps_n^{12-13}$$

· Diffusive Flux-Gradient approach :

$$F_{n+1/n} = D_{i+1/n}^{12-13} * \frac{C_{n+1}^{12-13} - C_n^{12-13}}{z_{n+1} - z_n}$$

$$= \left(D^{12-13} * \frac{\Delta C^{12-13}}{\Delta z} \right)_{n+1/n}$$

⇓

$$Ps_n^{12-13} = \frac{\Delta\left(\varepsilon_n * C_n^{12-13}\right)}{\Delta t} + \frac{\left(D * \frac{\Delta C}{\Delta z} \right)_{n+1/n}^{12-13} - \left(D * \frac{\Delta C}{\Delta z} \right)_{n/n-1}^{12-13}}{thick_n}$$

Determination of ε, D and C :

$$Ps_n^{12-13} = \frac{\Delta\left(\varepsilon_n * C_n^{12-13}\right)}{\Delta t} + \frac{\left(D * \frac{\Delta C}{\Delta z}\right)_{n+1/n}^{12-13} - \left(D * \frac{\Delta C}{\Delta z}\right)_{n/n-1}^{12-13}}{thick_n}$$

Soil cores sampled along the vertical profile

Relationship ε(SWC) and D(SWC) determined at the lab

The D(SWC) obtained is the $D12$(SWC) one, $D13$= 1.0044*$D12$

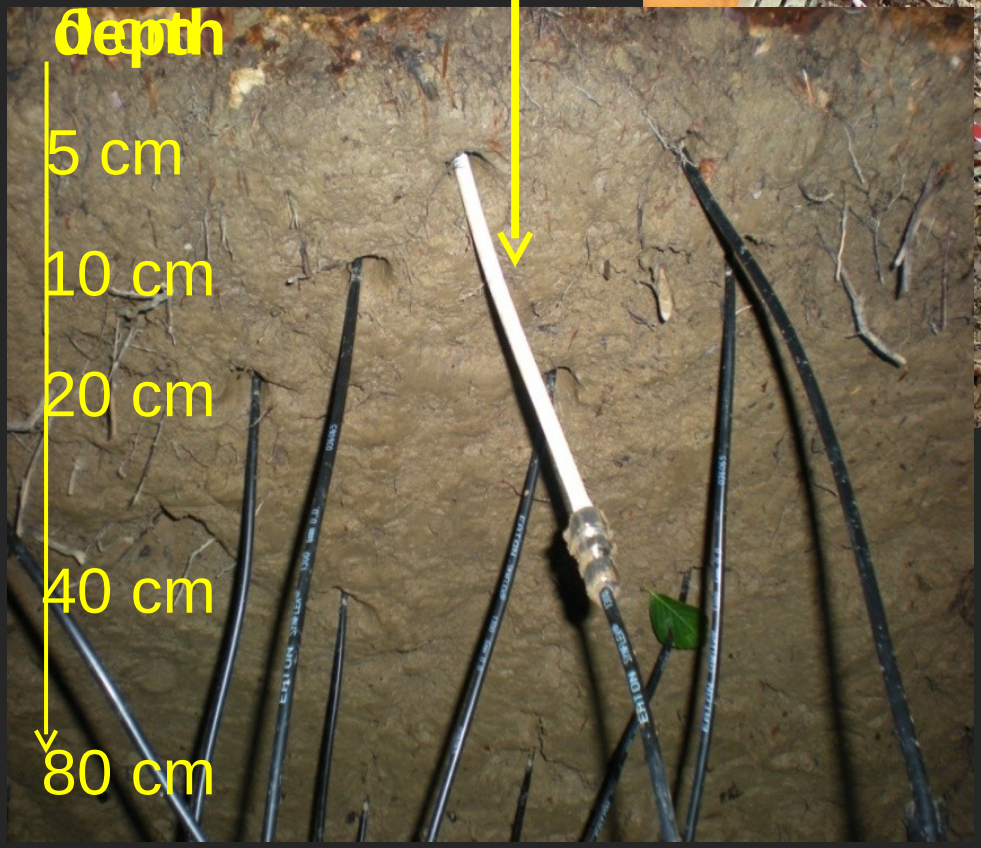
12CO2, 13CO2 and SWC vertical profile measured in the field

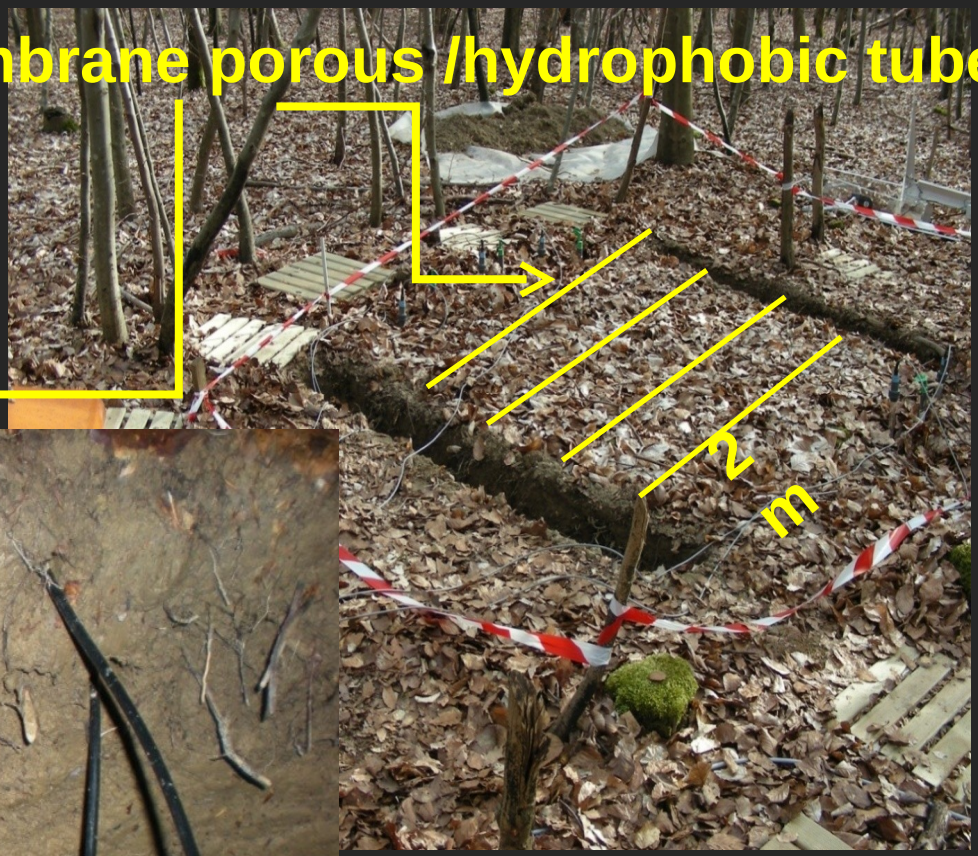
Boundary conditions : (***F* & *δF*)*bottom*** = 0; ***Fs*** and δ13***Fs*** measured

➡ ***Ps* and δ*Ps* for each layer**

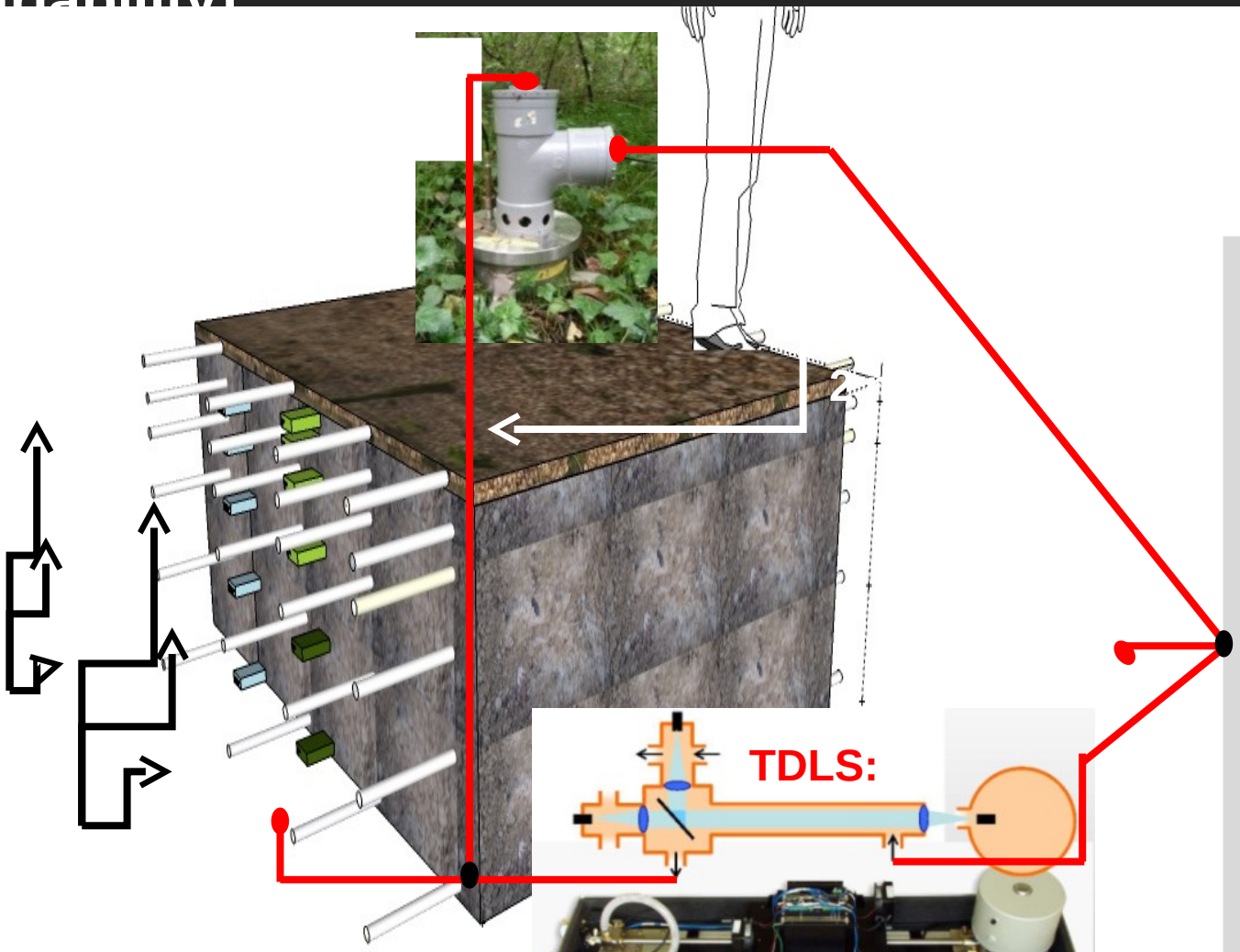
Field experimental device

(Parent et al. 2013)





In situ measurements during 21 days (intra-day variability)



TDLS:

12[CO2] &

13[CO2]

1) **Membrane tubes ⇨ [CO2] & *δ13*CO2 in soil layers**

2) **Chambers ⇨ *Fs & δ13Fs***

Site Descriptio n

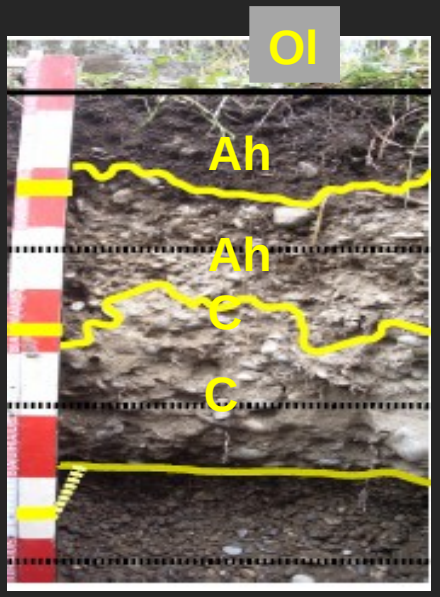


Hartheim experimental site

Slow growing 46 year old Scots Pine Forest (Pinus sylvestris L.)

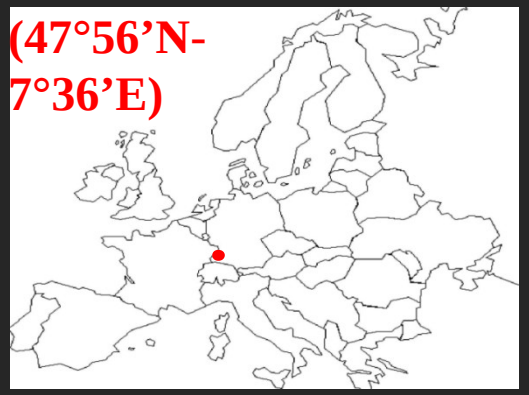
Mean annual air Temp:10.3°C

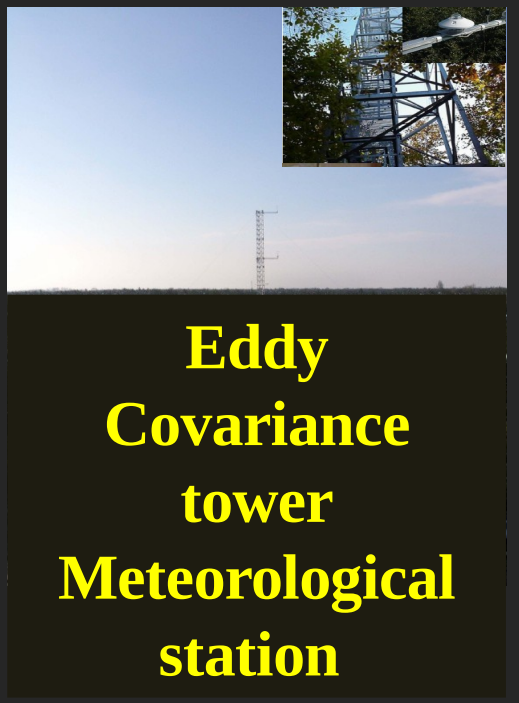
Mean annual precip: 642 mm



Haplic Regosol (calcaric, humic) (FAO, 2006)

Humus type is mull (1-3 cm thick)



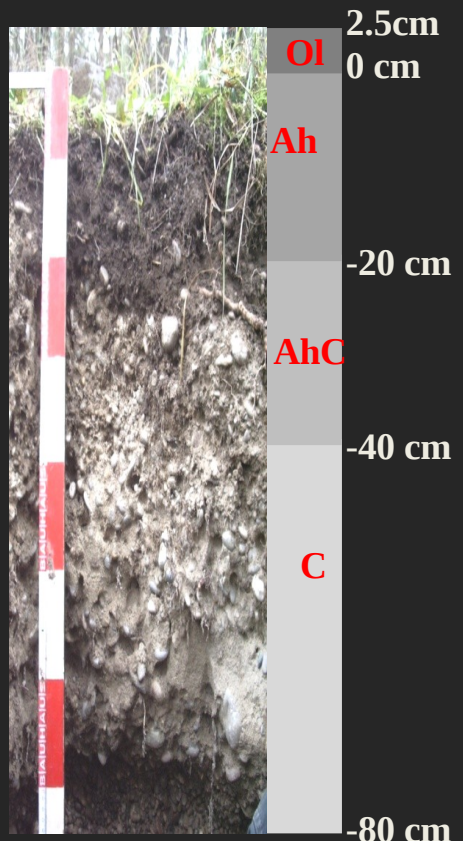


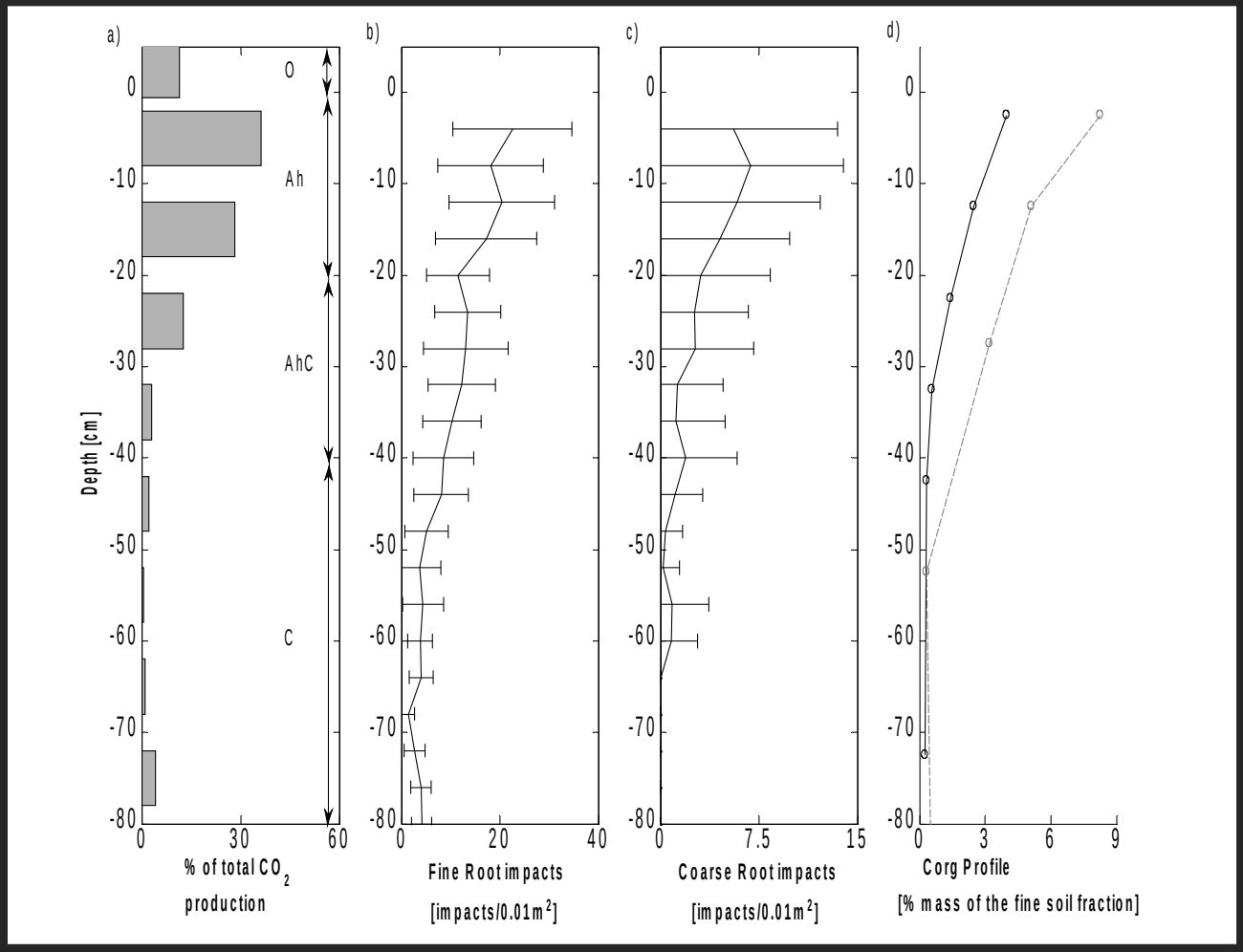
Eddy Covariance tower Meteorological station

1. Determine *Ps* and δ13*Ps* for ≠ layers

Vertical Profile of Ps

Horizon	%CO_2 Prod
Ol	11.5
Ah	64.7
AhC	15.8
C	8

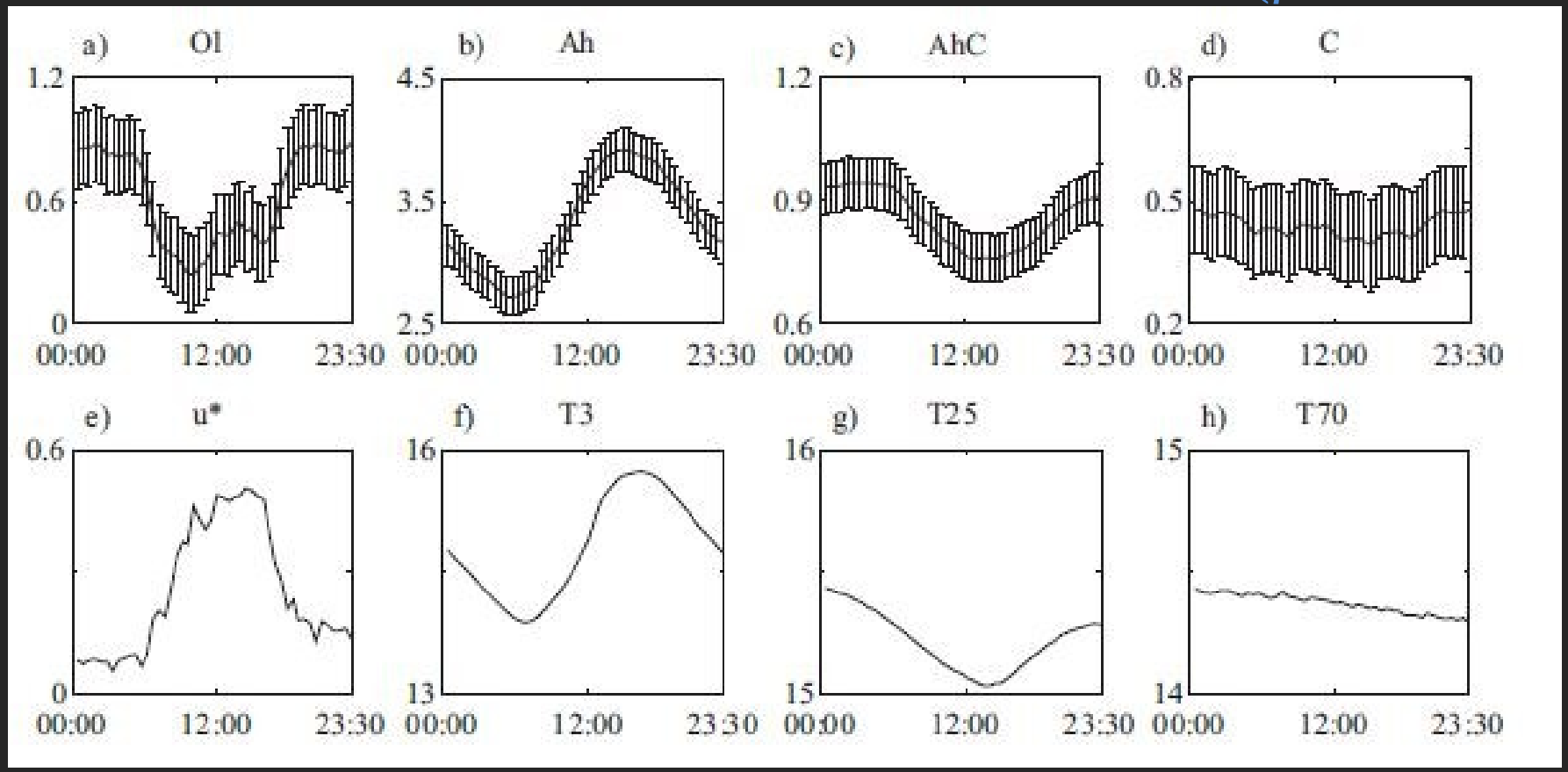




2. Factors affecting *Ps* and δ13*Ps* (Goffin et al. 2014)

Intra-day Ps variability

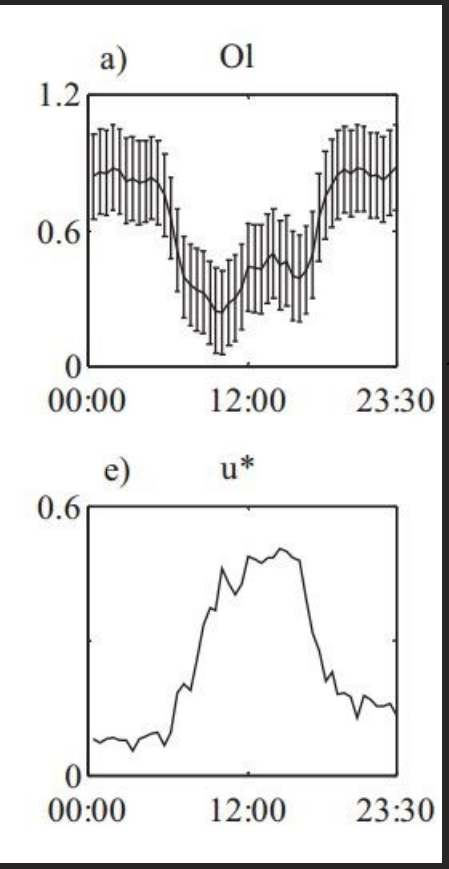
Ps mean diel evolution (µmol m-2 s-1)



Mean diel evolution of drivers

- Positively correlated to **LOCAL T°** in Ah & AhC
- Negatively correlated to u* in litter layer ???

Oh layer



u* is the driver of advective and dipersive fluxes !

➪ because of the total diffusive assumption

$$Ps_{computed} = Storage + Diffusion + Adv / Disp$$

$$Ps_{real} = Storage + Diffusion + Adv / Disp$$

$$\Rightarrow Ps_{computed} = Ps_{real} - Adv / Disp$$

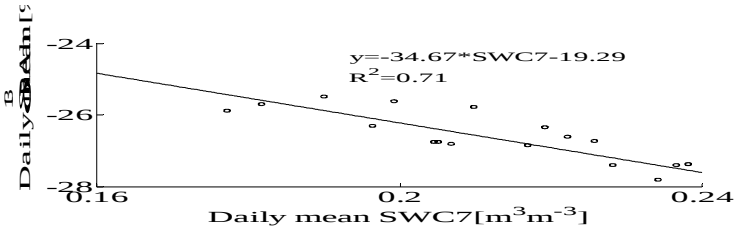
T° dependence

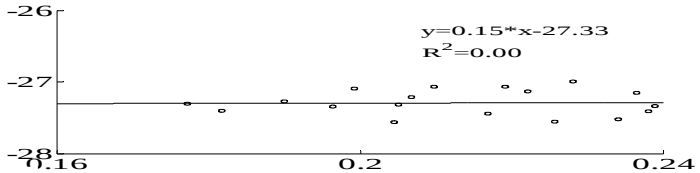
u* dependence

Inter-day δ13Ps variability

· **Significant day to day variations in δ13*Ps* of Ah (> 2.5‰)**

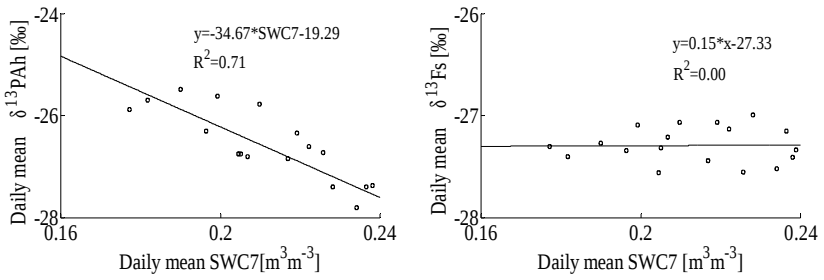
δ13*Ps* (‰)

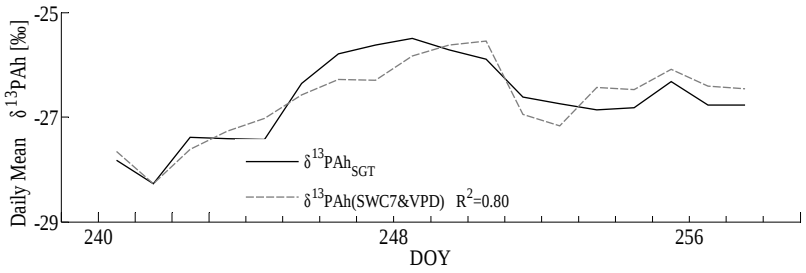




(SWC)

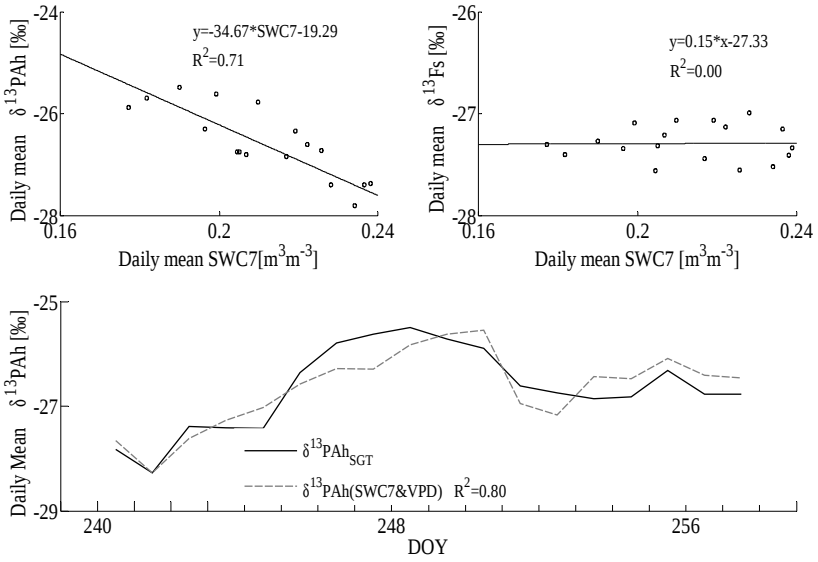
Julian day

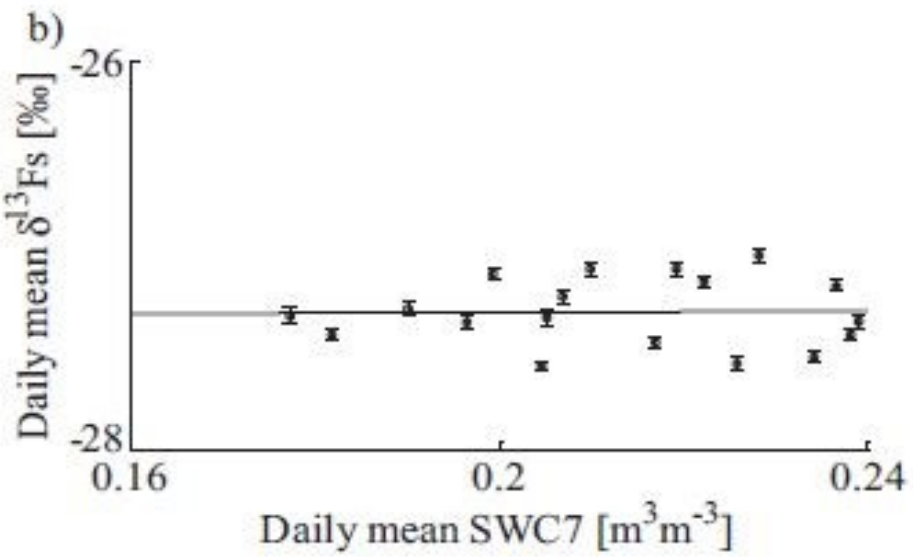




· **Best explained by soil moisture**

SWC decrease ⇨ enrichment
Same impact as for photosynthesis discrimination !!!





- **Enrichment not observed in chamber efflux measurements**
  - Mixing of ≠ layers contributions
  - Perturbation of soil climate below the chambers ?

3. Who (transport or production) is responsible for *Ps* and δ13*Ps* temporal variability ?

(Goffin et al. 2015)

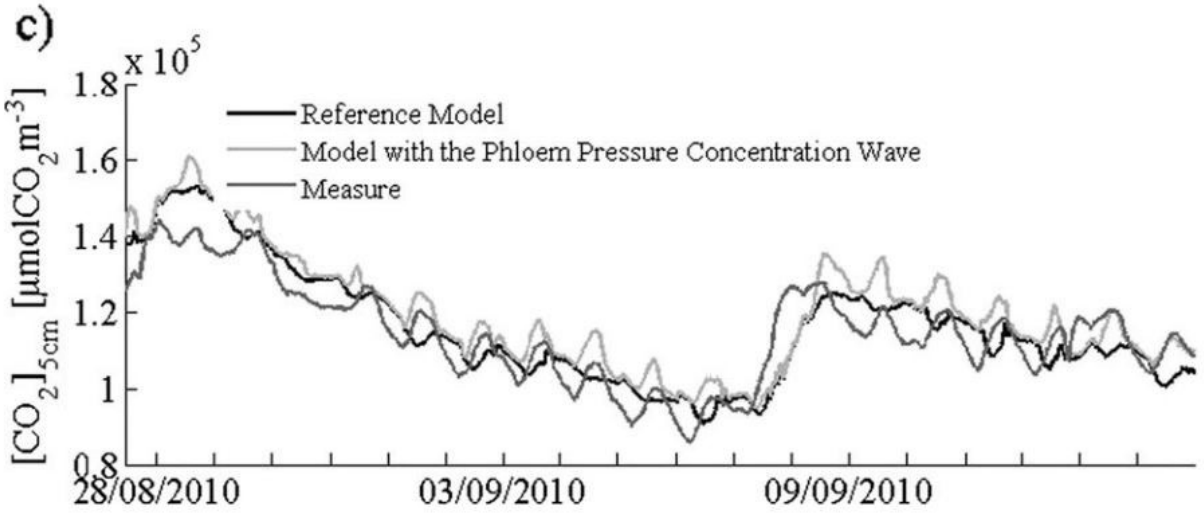
3 model versions simulating CO2 production and transport

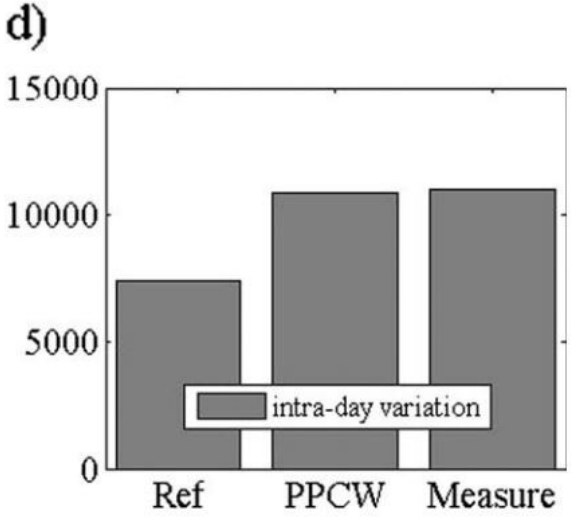
- Reference model (RM):
  Psn simulated with Q10 relationship using t° of the nth layer
  Diffusion is the only transport process
- Transport Version (TV):
  Advection and dispersion are added to diffusion
- Production Version (PV):
  In addition to T°, simulated production depend on VPD reflecting Phloem Pressure Concentration Wave (PPCW)

Comparison of RM, TV and PV outputs with soil [CO2] and *Fs* measurements

3. **Who (transport or production) is responsible for *Ps* and δ13*Ps* temporal variability ?**

RM: Relatively good reproduction of the general trend but intra-day variability too low and not in phase





- No significant improvement with TV
- PPCW : Not perfect but diurnal fluctuations are better reproduced and difference in phase is reduced

➡ **Working on production description before transport is a better option to improve soil CO2 model**

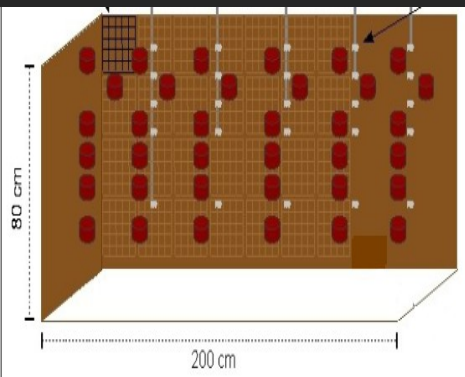
Key points

- Set up of an experimental *in-situ* device to obtain vertical profile of ***Ps*** and δ***Ps***
- Identify a dependence of horizons to their own temperature
- Observe enrichment of ***Ps*** with soil drought in Ah horizon
- Soil CO2 model should develop production description before transport to simulate hourly/daily variability

The End

Materials & Method

4. Laboratory Measurements



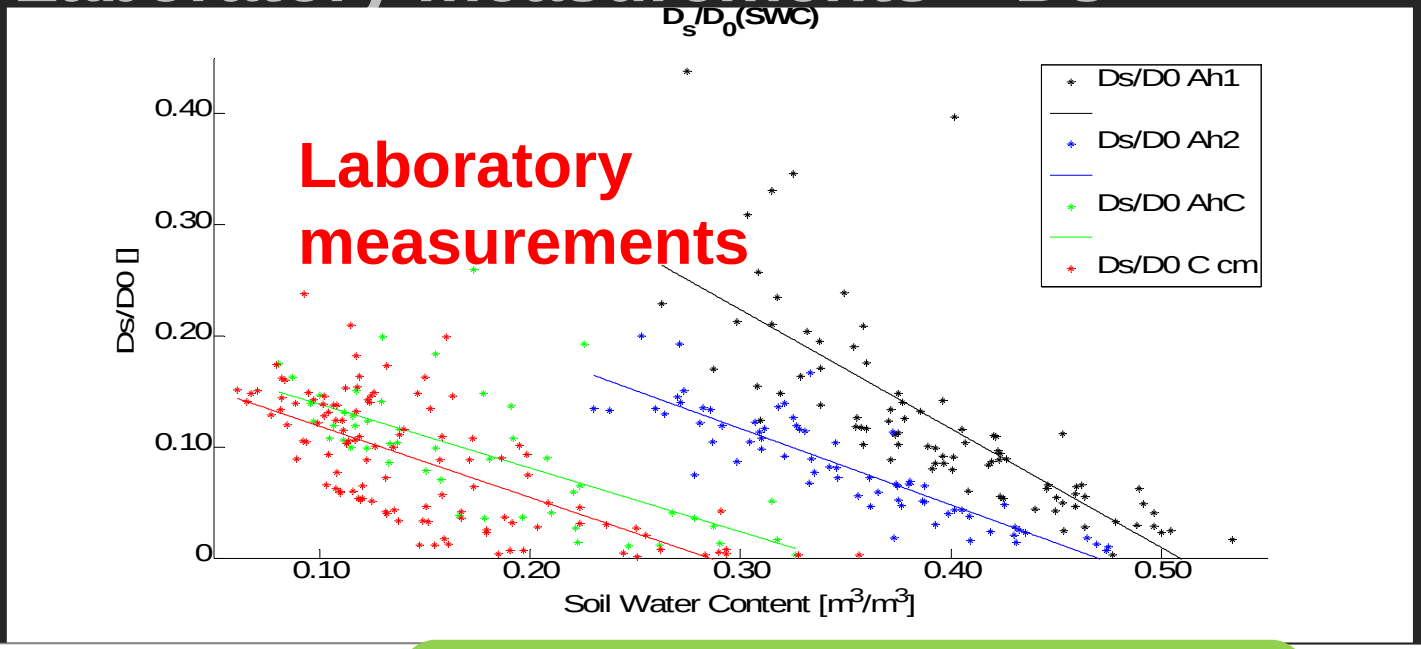
- Undisturbed soil cores of 200 cm3 collected in each horizon



- Soil horizon specific physical parameters :
  - Porosity, pF curves
  - Relationships between Ds(SWC)

Material & Method

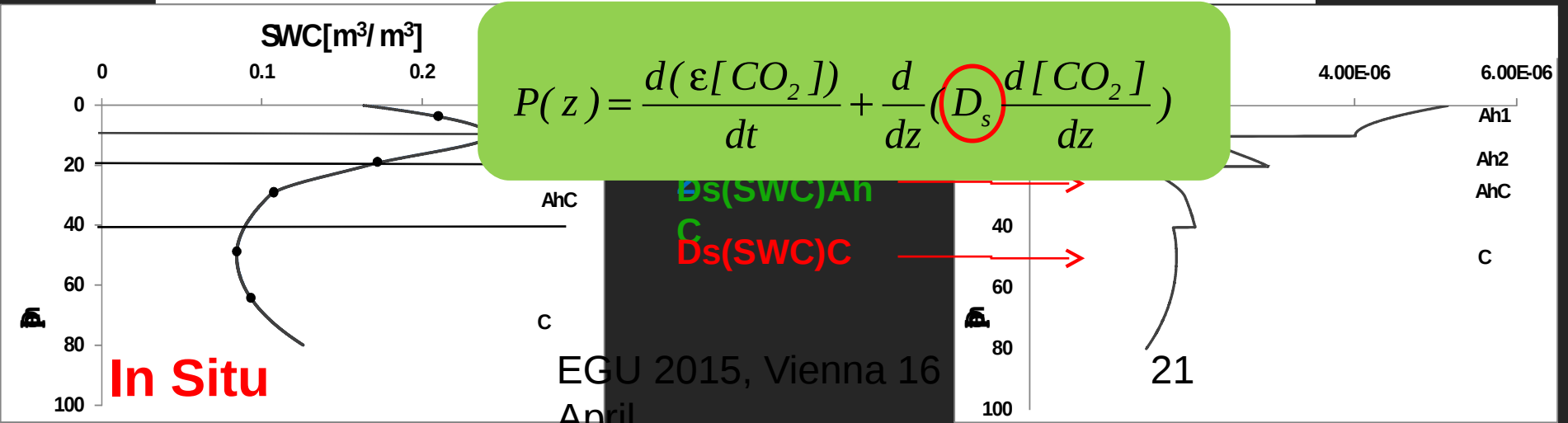
4. Laboratory measurements – Ds



$$P(z) = \frac{d(\varepsilon[CO_2])}{dt} + \frac{d}{dz}\left(D_s \frac{d[CO_2]}{dz}\right)$$

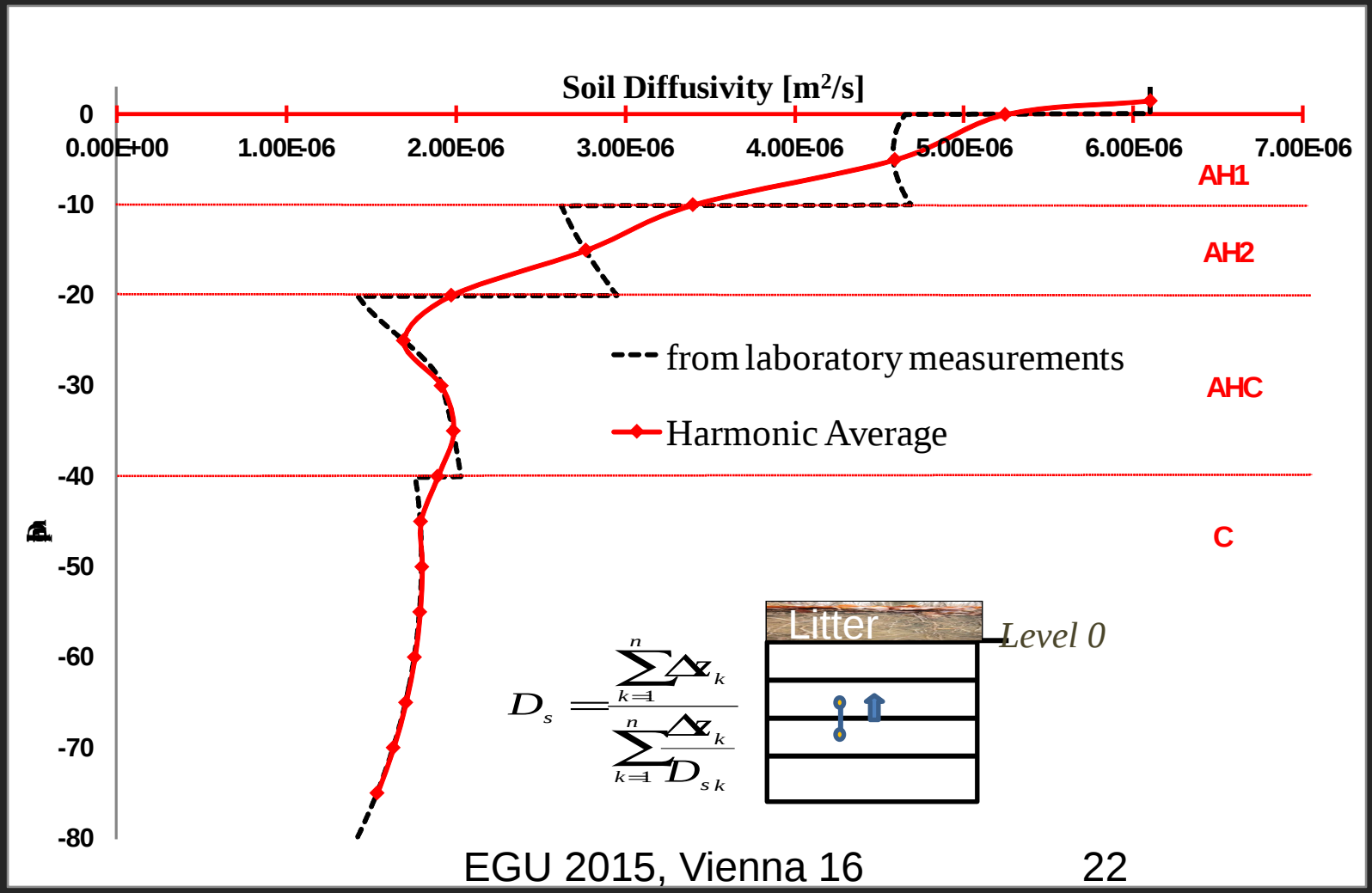
Ds(SWC)AhC

Ds(SWC)C



Materials & Method

4. Laboratory Measurements– Parametization



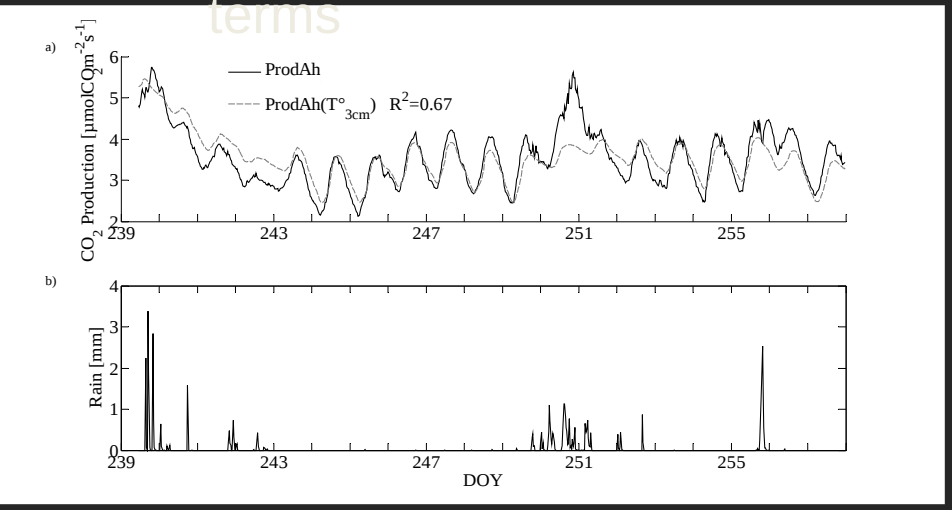
1. Determine Ps and δ13Ps for ≠ layers

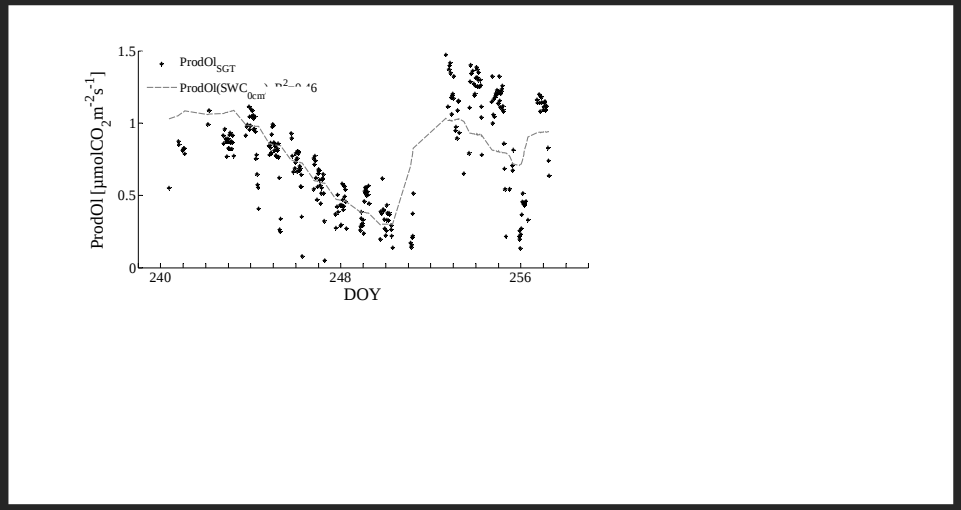
Day to day variation

Vertical Profile of CO2 sources

Ah Production terms

Litter Production terms





· Soil production shows clear diel and daily fluctuations in **Ah**

· The diel and daily fluctuations are best explained by the T measured in the topsoil
temperature is the most important driver of soil CO2 production

·Unlike other horizons, Ol production was best explained by surface soil water content (SWC) (R2=0.46)